HANDLING METAPHOR AND RELATED PHENOMENA IN HINDI

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by

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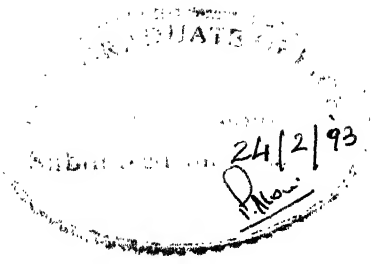
CERTIFICATE



This is to certify that the work contained in the thesis titled, **HANDLING METAPHOR AND RELATED PHENOMENA IN HINDI**, was carried out under my supervision by **Rajat Gopal** and it has not been submitted elsewhere for a degree.

February 1993
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To My Parents

ACKNOWLEDGEMENTS

The "acknowledgements" section of a dissertation may be the most pleasurable to write. It is certainly the most free-form, demanding the least formality and technicality. But definitely not the easiest. So much like METAPHORS — pleasurable to read and write, free-form, informal use in language, yet interpreting them is not the easiest job one can take at hand.

The signature on the certificate and much of the credit for this work belong to Rajeev Sangal, who served as my adviser. His attention and insight have made an indescribable contribution to this work.

Vineet Chaitanya made his contribution to many of the linguistic ideas in this work by providing education, inspiration and innovation.

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A number of other individuals contributed to the thesis by providing help on various aspects. Akum deserves a special thanks in helping me out with LaTeX and making figures. I sometimes feel he would have been much better off being an artist. Sarkari, Hsahu, and Ashishp also have a hand in this thesis getting its present shape and form.

Now for the hard part: I can't possibly acknowledge all the people who didn't contribute to this thesis in the least, but instead contributed to making life a lot more fun and interesting. They include all my classmates here at IIT-K and some others. Two names deserve a special mention. Vasudev, who was a friend, philosopher, and guide to me and Chinmoyee, a true friend in the truest definition of the term.

The hardest part: When I started on this work it might have been the most important thing to me. As I finish, it lags behind the bonds I have formed with people such as those mentioned above and whose memories will be with me long after I've forgotten what I've written here. It's hard to separate one's personal life from one's thesis — no metaphor intended.

Abstract

Metaphor is an integral part of any language usage. Little effort has gone into developing a mechanism to handle metaphors in Hindi language. This thesis is concerned with the design and implementation of a mechanism to handle metaphor and related phenomena in Hindi under a common knowledge framework. We propose a computational theory of metaphor which explains how metaphors originate, how they can be classified on the basis of their origin, and how this classification scheme greatly simplifies the interpretation process. We believe that every verb has a primary sense corresponding to its common or preferred usage. Most metaphors are in effect verb usages in a sense different from their primary or preferred sense and it is the semantic environment in which they exists that gives them a particular sense. With the approach to interpretation of metaphors in Hindi presented in this thesis, only knowledge associated with the primary sense of the verb need to be represented and other verb senses can be obtained by transforming the knowledge associated with the verb's primary sense. Metaphor related phenomena like simile and metonymy can also be handled under the same knowledge framework but by replacing or expanding the noun terms in the sentence. We also formulate a measure of conceptual closeness of verbs and show how it can be useful in the interpretation of metaphors.

Contents

List of Figures

Chapter 1

Introduction

Metaphor suffuses human language, yet they have long been relegated to the background in the field of Natural Language Processing. The history of the field of metaphor is shrouded in mysticism and awe. Researchers in NLP, have often wondered if metaphor is a mere fanciful use of language, testifying to human's playful side, or are there interesting computational advantages to be gained from the processing of metaphor in language. Where do metaphors originate ? Are there metaphors common to all languages and cultures ? This thesis is concerned with the problem of interpreting metaphors in Hindi language and tries to answer the queries posed above.

1.1 The Task of Metaphor Interpretation

One good reason to focus on this problem is that relatively little research has directly addressed the task of interpreting metaphors in Hindi.

Consider some of the problems associated with understanding the metaphoric language in the following sentences.

(1) rAma ne buKAra *pakada* liyA
राम ने बुखार पकड़ लिया
Ram fever catch
(Ram caught fever)

(2) maSIna bijalI *KAtI* hE
मशीन बिजली खाती है
machine electricity eat
(The machine eats electricity)

(3) gADI petrola *pItI* hE
गाड़ी पैट्रोल पीती है
vehicle petrol drink
(The vehicle drinks petrol)

The italicized words in each of these examples are being used to metaphorically refer to concepts that are quite distinct from those that might be considered the normal meanings of the words. In (2), *KA* (eat) is being used to refer to excessive consumption of electric power by a machine. This

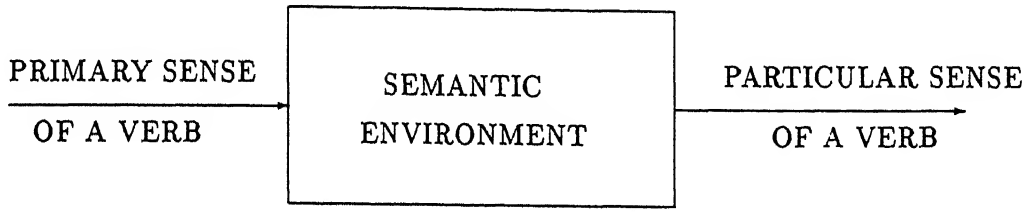

Figure 1.1: Verb Sense Transformation.

use is clearly different from what might be called the primary or preferred meaning of the word that has to do with the actions that result in swallowing of food by a living being.

The metaphorical use of *KA* in (2) results from a systematic metaphor that allows actions and states that have to do with eating of food to refer to actions and states that have to do with excessive consumption of some fuel by machines while in operation.

1.2 The Sense Transformation Approach

The main thrust of the approach to metaphor presented here is that it is the *semantic environment*, consisting of other words occurring in the sentence that have some case role assigned to them, in which a word exists that gives the word a particular meaning. In (3), The semantic environment of the verb *pI* (drink) consists of the noun terms *maSIna* and *bijalI*. We also propose that most metaphorical usages are verb centered. In all the three examples mentioned in 1.1, it was the verb that was being viewed metaphorically. We take the stand that almost every verb has a primary sense and all other senses of the verb can be derived from this primary sense. Now we can view this semantic environment, consisting primarily of nouns, as a transformation function acting on the primary sense of the verb and yielding other senses of the verb.

In examples (2) and (3), it is important to note that though *pI* and *KA* ordinarily denote different actions, they are used in a similar sense — that of excessive consumption. We also look into this question as to what makes two different words take similar senses.

The approach to metaphor, described here, associates with the verbs such characteristic features that correspond to its primary sense which is also its common and preferred usage. We propose a mechanism whereby the sense of the verb in a metaphorical usage can be derived from its primary sense. When a metaphorical usage is encountered, the above mentioned transformation function is applied to the characteristic features associated with the primary or preferred sense of the verb, thereby yielding the underlying metaphor involved. We also describe how these characteristic features can be used to formulate a measure of conceptual closeness of words and how this helps us in the task of metaphor interpretation. The processing of example (3) is illustrated below.

Input sentence	:	gAdI petrola pItI hE
Interpretation	:	gAdI petrola aDika Kapata karatI hE
Underlying metaphor	:	pInA = aDika Kapata karnA

The above interpretation process can be viewed as shown in Figure 1.1

The term metaphor has historically been applied to a wide range of disparate phenomena. Our approach not only covers metaphors but also similes, analogies and metonymies, all of which we

believe are special cases of a more general phenomenon. We propose a unified theory of metaphor and a knowledge representation scheme which provides a common knowledge framework for all these related phenomena, though the methodology adopted during interpretation process for handling each case is slightly different.

The verb-centered approach is not applicable to similes and metonymies which classified (discussed in chapter 5) as noun-centered metaphors. For handling these cases, knowledge about the roles noun terms play in real world is encoded in the knowledge-base.

1.3 Previous Approaches

While there is no evidence of development of a computational model of Hindi metaphor interpretation to date, most parsing strategies developed in the context of Indian languages use the word-sense approach to deal with the conventional uses of words that deviate from primary, or preferred, meaning. The word-sense approach addresses this problem by listing each separate use as an isolated and unmotivated word-sense in the lexicon. While this approach adequately allows known conventional senses to be interpreted correctly, it has a number of shortcomings.

The first shortcoming involves a representational issue. The listing of each separate use as an individual fact in the lexicon fails to capture the systematicities among senses of different words or among the senses of a single word. This enumeration of each use as an isolated and unmotivated fact about the language leads to the second more critical shortcoming. The lack of structure in the lexical knowledge-base makes it difficult to predict or classify the meaning of new uses when they are encountered.The approach presented here is an attempt to capture the rich conceptual structure that gives rise to them.

In our approach, we attempt to account for how a word aquires different senses. Our approach also makes use of world knowledge in representing the knowledge associated with each lexical entity.

1.4 The Thesis

The claim of this thesis is that by associating particular features with the primary sense of the verbs and including such knowledge about nouns, that could possibly be highlighted in a metaphorical usage involving that noun, in the knowledge representation framework the need for any explicit representation of metaphoric knowledge can be eliminated for accomplishing the task of metaphor interpretation. Also, that a unified approach to handle not just metaphors but also related phenomenon like simile and metonymy is feasible. The support of this thesis lies in the nature of the representation and the successes of the implementation.

Chapter 2 presents an overview of research on metaphors, focusing on the theory and implementation of existing systems and highlighting some of the practical problems with these systems. The discussion is meant to provide an update of the state-of-the-art in metaphor interpretation as well as the motivation for the work presented here.

Chapter 3 presents the fundamentals of our approach to the problem of metaphor interpretation.

Chapter 4 covers in detail the knowledge representation framework, a set of tools for the representation of linguistic and conceptual knowledge, and provides examples of the knowledge encoded.

Chapter 5 shows how the knowledge representation framework discussed in chapter 4 is applied to the task of metaphor interpretation. It discusses the process of metaphor recognition and classification before providing details about the interpretation process.

Chapter 6 analyzes the contribution of this work and suggests areas for future research.

One appendix is provided to give a brief description of the Paninian formalism.

Chapter 2

Survey of Metaphor Research

Little or no reference has been found to work on interpretation of metaphors in Indian languages. This chapter deals with metaphor research that has been carried out on English and other languages in the West.

The phenomenon of metaphor is so poorly understood that widely divergent views exist about it. This discussion reviews some of the relevant research on metaphor both from theoretical and computational viewpoint.

2.1 Metaphor: A Theoretical Perspective

Five views of metaphor are critically discussed: the substitution view, the comparison view, the interactive view, the selection restriction violation view, and the conventional metaphor view.

2.1.1 The Substitution View

The basic premise of all substitution theories is that metaphor involves some kind of semantic abstraction but they differ in their approach to its operation. It generally takes two forms:

- identifying the tenor in metaphor *in absentia.*
- substituting the second term of the metaphor (the vehicle) by its 'properties', that is, semantic features.

The logical space of van Dijk

In van Dijk's [3] 'Sortal Semantics' each predicate of a language is conceived to be surrounded by a set of concentric circles of sortal categories reflecting hierarchy of increasingly abstract semantic features. Conversely, each predicate is assigned a REGION OF LOGICAL SPACE, a conceptual network or a set of 'possible objects' such that 'the predicates of language can either apply or not apply to these possible objects'.

Interpretation involves reconstruction (adhoc) of the logical space of the predicate so that the given subject could come within the region of the possible objects of the predicate. For example in

(4) Peter preferred to pick one of the local flowers.

"the predicate 'flower' is extended such that its region comprises not only flowers but also girls (in a given context)"

Haley's psycholinguistic approach

In Haley [5] the logical space of van Dijk is transformed into 'psycho-lexical space' (ordered categories of the levels of generality that hold between semantic categories of a language. At the center is 'intellection' (pertaining to 'human') followed by 'animation' (pertaining to 'animals'), 'life' pertaining to 'trees, flowers' etc.), 'shape' (pertaining to 'rock, balls' etc.) and so on arriving finally at 'being' (pertaining to 'truth, beauty' etc.). The use of this perceptual space can be explained with an example by Haley himself: (5) Every rock speaks volumes.

'Speaks' from the category of Intellection is displaced to that of shape (to which 'rock' belongs) thereby creating tension between the now more abstract 'speaks' and the more concrete 'rock'. The human features of 'speaks' (+ symbolic communication, + human, + articulate, + vocal) are now detatched as a consequence of this abstraction resulting in a 'reconstruction of meaning' as an 'abstract configuration' so that 'speaks' now configures as [+ symbolic] communication and can be predicated to 'rock'.

The substitution theories focus on the extinction of the vehicle and finding its 'literal' equivalent, that is, either the tenor or the properties of the object referred to by it thus giving a sense of finiteness to metaphoric meaning. But they fail to explore the relationship of vehicle with the tenor.

2.1.2 The Comparison View

According to the comparison view a metaphor is a comparison in which one term(the tenor or subject of the comparison) is asserted to bear a partial resemblance (the ground of the comparison) to something else (the vehicle), the resemblance being insufficient to sustain a literal comparison. As with any comparison, there is always some residual dissimilarity (the tension) between the terms involved in the comparison, but comparison theorists tend not to emphasize this dissimilarity.

What is crucial in the comparison approach is finding the correct ground in a metaphor. Tourangeau and Sternberg reduce the principles for finding the ground of a metaphor to two basic ones: finding a category to which the tenor and vehicle belong and constructing an analogy involving them.

Tourangeau and Sternberg [11] list some problems with the comparison view, including the following:

- that everything has some feature or category that it shares with everything else, but we cannot combine just any two things in metaphor.
- that the most obvious shared features are often irrelevant to a reading of a metaphor.
- that even when the feature is relevant, it is often shared only metaphorically.
- that metaphors are novel and surprising is hard to reconcile with the idea that they rely completely on extant similarities.

The comparison theory tries to circumvent the experienced semantic strain by interpreting metaphor as nothing but a way of comparing two things to see in what respects they are alike. And since any two things are similar in some respects, this kind of theory can never explain what is interesting and important about metaphor.

2.1.3 The Interaction View

The interaction view focuses more upon the surprise and novelty the metaphors create.

Interaction theorists argue that the vehicle of a metaphor is a template for seeing the tenor in a new way. This reorganisation of the tenor is necessary because the characteristics or features of the vehicle cannot be applied directly to the tenor; the features they 'share' are often only shared metaphorically. As Black [2] observes, the ground of a metaphor may itself be nonliteral. 'Men are Wolves,' in Black's example, in part because both are predators; but they are predators in sharply different senses that may only strike us similar when we interpret the metaphor. In Black's reading of this metaphor, we see competition in social relations as corresponding to predacity in beasts.

A problem with the interaction view is that the theorists have not provided much detail about the processes involved, though Black [2] does make some suggestions.

According to Black, tenor and vehicle have a 'system of commonplaces' associated with them. These commonplaces are stereotypes, not necessarily definitional, not even necessarily true, just widely agreed upon. In interpreting 'man is a wolf,' we 'evoke the wolf-system of related commonplaces' and are led by them 'to construct a corresponding system of implications about the principal subject (Man)'. In Black's view, then, interpretation involves not so much comparing tenor and vehicle for existing similarities, as construing them in a new way so as to create similarity between them.

One might distinguish, then, two main differences between the interaction and comparison views. First, similarities are "created" in the interaction view (accounting for the novelty and surprise in the metaphor) whereas only pre-existing similarities are found in comparison view. Second, a whole system of similarities are evoked between tenor and vehicle in the interactions view, whereas the comparisons view is based upon finding a single similarity.

Interaction is the fullest explanation of the role of language in metaphor. It takes into consideration both similarity and dissimilarity in metaphor and does not simply try to eliminate the latter. Despite certain inadequacies, in any model of metaphoric interpretation interaction has to be at the core.

2.1.4 The Selection Restrictions Violation View

The selection restriction violation view has also been called *the semantic deviance view* and *the anomaly view.*

Metaphor constitutes a violation of selection restriction rules within a given context, where the fact of this violation is supposed to explain the semantic tension one experiences in comprehending any live metaphor.

The main problem with the selection restrictions view is that perfectly well-formed sentences exist that have a metaphorical interpretation and yet contain no selection restriction violations.

So whether or not a sentence is a metaphor depends upon the context in which it used.

For example,

(6) My car drinks gasoline.

is an instance of preference violation for the verb - 'drinks' which takes an animate subject.

2.1.5 The Conventional Metaphor

Lakoff and Johnson [13] have popularized the idea of conventional metaphors, also known as conceptual metaphors. They distinguish three main kinds: orientational, ontological, and structural. Orientational metaphors are mainly to do with kinds of spatial orientation like up-down, in-out, and deep-shallow. Example metaphors include **more is up** and **happy is up**. They arise from human experience of spatial orientation and thus develop from the sort of bodies we have and the way they function in our physical environment.

Ontological metaphors arise from our basic human experiences with substances and physical objects (especially our own bodies). Some examples are **time is a substance**, **the mind is an entity**, and **the visual field is a container**.

Structural metaphors are elaborated orientational and ontological metaphors [13] in which concepts that correspond to natural kinds of experience, e.g., **physical orientations**, **substances**, **war**, **journeys**, and **buildings**, are used to define oher concepts, also natural kinds of experience, e.g., **love**, **time**, **ideas**, **understanding**, and **arguments**. Some examples of structural metaphors are **argument is war** and **time is money**.

What Lakoff and Johnson do not discuss is how metaphors in general, let alone individual metaphorical concepts, are recognized.

2.2 Computational Approaches to Metaphor

The development of computational models of metaphor interpretation has been the focus of only a small body of research. The task of metaphor interpretation, however, has evolved under the constant influence of advances and trends in Artificial Intelligence, Linguistics, Philosophy, and Psychology.

2.2.1 Knowledge-Deficient Approaches

The principle characteristic of the approaches described in this section is that metaphor is treated as a departure from conventional language. Moreover, because these approaches do not consider metaphor from a conventional perspective, explicit knowledge about the metaphors in the language is not available to these approaches. This complete lack of explicit knowledge about the metaphors leads to the term knowledge-deficient.

Natural Language Processing Approaches

The approaches described in this section are explicitly concerned with natural language processing issues. That is, they are actually concerned with the task of interpreting sentences containing metaphors.

The presence of a selection restriction violation is taken as evidence for the existence of metaphor.

Wilks

Wilks developed a series of approaches to metaphor centered around the notion of *preference semantics*. His work was partially a reaction to the work on lexical semantics by Katz and Fodor [7] which gave rise to the idea of selection restrictions.

(7) My car drinks gasoline.

According to the selection restriction approach, the verb drink requires that the drinker be an animate. The above sentence is simply not well-formed because the actor is a car and not animate. He proposed the notion of a *preference*, As far as metaphor was concerned, the initial use of preferences was to simply recognize a potential metaphorical use when a preference restriction was violated.

In [12] the notion of simply accepting a metaphorical preference violation was replaced with the notion of a *projection* using a knowledge structure called pseudo-text. A pseudo-text was a script-like representation of some episodic or contextual information about the target domain. The process of projection replaced the item with the violated preference with a relevant concept from the pseudo-text.

A major problem with this approach, and with all the selection restriction approaches, is the reliance on selection restriction or preference violations. Thus those sentences which involve no violations of the literal semantics but have an obvious conventional metaphorical meaning go undetected.

Fass

Fass [4] introduces an approach of lexical semantics called Collative Semantics (CS). CS builds on and extends the preference semantics approach of Wilks. Fass discusses a mechanism to distinguish metaphor from metonymy and provides details about their interpretation process.

Fass, like Wilks, adopts the basic approach of detecting a metaphor by noticing a selection restriction violation and then replacing it with some target concept. Fass provides the details of an approach to this problem by using an abstraction hierarchy. The basic assertion is that the intended target meaning will be a sibling of the source concept in an abstraction hierarchy. The search for this sibling is guided by the target concepts in the input example.

Russell

Russell uses Conceptual Dependency [9] as her underlying knowledge representation. Violations of selection restrictions were modeled as violations of the restrictions on the various roles in CD primitives. Consider the following example.

(8) She offered him an idea.

According to Russell, the essential source concept in this example involves a hypothetical **PTRANS**. (An offer of transfer of physical possession). However, the concept, *idea*, filling the role of the object transferred, violates the requirements for that role imposed by the **PTRANS** primitive. The filler of the transferred role must be a physical object. The intended target concept involves an **MTRANS**, representing the offered communication of the idea from the actor to the recipient.

Russell demonstrates how a structure matching system can exploit the structure of these violations to actually determine the intended target meaning of the metaphor.

Analogical Approaches

The approaches described in this section are mostly research efforts concerned with analogical reasoning processes. Most make the assertion that while they are not explicitly dealing with metaphor their approaches nevertheless extend to the interpretation of metaphor. In particular, these approaches assert that the meaning of a mataphor results from an analogically directed transfer of relations from the source to the target domain.

Indurkhya

Indurkhya's [6] Constrained Semantic Transference theory of metaphor can be viewed as a formalization of Black's interaction theory. Source and target domains are viewed as "systems of relationships." In metaphorical interpretation, an "implicative complex" of the source domain is imposed on the target domain, thereby shaping the features of the target domain, which in turn produces changes in the features of the source domain, hence the "interaction." It is assumed that a structural analogy underlies every metaphor.

Winston, Carbonell, Gentner, Greiner and Burstein too arrive at solutions to the problem of interpreting and producing metaphors via analogical reasoning. They assert that the meaning of a metaphor results from an analogically directed transfer of relations from the source to the target domain.

2.2.2 Knowledge-Based Approaches

Martin [8] takes the metaphoric knowledge approach to the interpretation of metaphors. His methodology is based on the premise that metaphors are not a matter of novelty, but are rather a conventional part of our conceptual system. He has pursued a conventional metaphor view using KODIAK, a knowledge representation language. Within KODIAK, metaphorical relations are represented using a primitive link type called a "VIEW." A VIEW "is used to assert that...one concept may in certain circumstances be considered as another". In Martin's work, "metaphor-maps," a kind of VIEW, are used to represent conventional metaphors and the conceptual information they contain.

2.3 Analysis

Among the computational approaches Martin's knowledge based approach has by far been the best in terms of number and variety of metaphors that it can handle. But Martin makes no mention of how many conventional metaphors are there and how this basic set is to be acquired.

Among knowledge deficient approaches Indurkhya proposes a sound theory based on analogy but points out that his approach is computationally intractable. The obvious problem with the approach of analogy transfer is the exponential number of possible configurations that have to be considered. If there are N concepts in the source and target domains then there are N! possible configurations to consider.

In Chapter 3, we will discuss how we refine and incorporate some concepts of both the above mentioned approaches in the computational theory of metaphhor that we propose. In particular, we embedd some of the most basic metaphors in the knowledge framework associated with each domain and use an augmented analogical approach with domain specific knowledge that limits the number of configurations considered.

Chapter 3

A Computational Theory of Metaphor

3.1 Introduction

What we attempt here is to develop a computational theory of metaphor interpretation for Hindi, but as far as possible we aim at making our theory relatively independent of idiosyncracies of specific language and which can hold good at least for all Indian languages.

We take the position that analogies, similes, scientific models, metonymies, metaphors, etc., are all special cases of a more general phenomenon. Though each of them has its own distinguishing features, there are some general characteristics that are common to all of them and one should be able to capture them within one unified theory.

We start from the assumption that metaphors are characterized by the description of one domain, called the target domain, in terms of another domain, called the source domain. Further, in a metaphor some terms of the target domain may be mentioned along with some terms of the source domain or — as is often the case with poetry and other forms of art — there may not be any explicit mention of the target domain.

Indurkhya [6] makes use of the following paradigm in developing a computational theory of metaphors :

1. Choose some appropriate formalism for representing the knowledge assosiated with a domain. This representation should be as independent of idiosyncracies of specific domains as possible. In other words, we should not include some feature just because it seems natural for a particular domain.

2. Formalize the notions of metaphor in the representation chosen in the previous stage. It should be possible to explain as many of the cognitive properties of metaphors in this characterization as possible.

3. Design and implement computer models of the cognitive processes involved in comprehending and generating metaphors. In designing these models one could make use of the peculiarities of domains being modelled for efficiency reasons but it will be desirable to separate the principles that are a consequence of the formalization from those that are domain dependent.

4. Use the experience gained from these models to revise the formalization and/or the knowledge representation scheme and go back to the previous stage.

We adopt this paradigm in its generalized form and this chapter addresses its first two stages and the third stage is covered in Chapter 5 while discussing the implementation details.

We list the characteristics of metaphors that we are assuming :

- Analogies, similes and scientific models may be seen as special cases of metaphors. Thus, every time we use the word "metaphor," we mean metaphors, analogies, similes and scientific models.
- Metaphors use term(s) belonging to one domain, called the source domain, to refer to object(s), other than their conventional referents, belonging to a possibly different domain, the target domain.
- There is no basic unit of metaphors in discourse. Thus, a word, a phrase, a sentence, a passage or a whole book can be metaphorical. But to make the problem of metaphor interpretation well defined and computationally feasible, we treat word as the unit of metaphor.
- A metaphor can be subject to several interpretations.
- Metaphors highlight certain parts of target domain whereas they downplay certain others.
- Sometimes one metaphor can express what would normally require several literal statements.
- Metaphors redescribe the target domain in terms of the source domain. Different metaphors yield different descriptions of the same target domain.
- Metaphors also play a role in the process of meaning change. A new metaphor through repeated use can become *dead*, that is, have literal meaning.
- Both source and target domains participate in giving an interpretation of metaphors.
- Human comprehension of metaphor is rich in knowledge about the basic metaphorical forms.

3.2 The Need for a Computational Model

In order to develop a formal theory of metaphor for Hindi language, we start from the interaction theory of metaphor proposed by Black [2]. We take the stand that metaphors arise out of interaction or correspondence between two domains (represented by words in our model). So any part of speech, generally speaking, could interact or correspond to give rise to a metaphor. Now, even for a not so large vocabulary, listing all such possible interactions in all possible contexts is a virtually impossible task. A metaphor interpretation system can deal with such interactions dynamically.

3.3 Representational Requirements

Now we discuss the basic requirements for representing knowledge about metaphors. We have already shown that the knowledge of the metaphors in the language cannot be adequately captured by merely listing the details of each one individually. The set of metaphors in the language, taken as a whole, demonstrates certain regularities. Hence the representation of metaphorical knowledge should be such that it captures these regularities in their most general form.

Consider the following examples.

(9) gAdI petrola pItI hE
गाड़ी पेट्रोल पीती है
vehicle petrol drinks
(The vehicle drinks petrol)

(10) rAma kA dila tUta gayA
राम का दिल टूट गया
Ram's heart break
(Ram's heart broke)

(11) rAma kA dimAga nahiM cala rahA hE
राम का दिमाग नहीं चल रहा है
Ram's mind not work
(Ram's mind is not working)

(12) rAma wo hAtI hE
राम तो हाथी है
Ram elephant
(Ram is an elephant)

(13) rAma ne gilAsa pI liyA
राम ने गिलास पी लिया
Ram glass drink
(Ram drank the glass)

All of the above sentences lend themselves to metaphorical interpretations. The question that arises is what makes one concept to be viewed in terms of another, a theme central to metaphor comprehension.

In all the above sentences except (12), the metaphor arises out of the interaction between a noun and a verb. In (12), the interaction is between two nouns. In fact barring direct analogy or simile as is the case in (12), metaphors predominantly arise out of noun-verb interaction.

Consider the following sentences with verb *pI.*

(14) gAdI petrola pItI hE
गाड़ी पेट्रोल पीती है
vehicle petrol drinks
(The vehicle drinks petrol)

(15) jamIna pAnI pItI hE
जमीन पानी पीती है
earth water drinks
(The earth drinks water)

(16) rAma pAnI pItA hE
राम पानी पीता है
Ram water drinks
(Ram drinks water)

In the first case *pI* takes the sense of *aDika Kapata karanA* (excessive consumption)
In the second case *pI* takes the sense of *soKanA* (absorption)
In the third case *pI* takes the sense of *pInA* (normal drinking activity)

So we see that it is the semantic environment in which a verb exists that gives it a particular meaning. What we propose here is that almost every verb (a few exceptions cannot be ruled out) has a primary sense and all other senses of the verb can be derived from this primary sense. Now we can view this semantic environment, consisting primarily of nouns, as a transforming function acting on the primary sense of the verb and yielding other senses of the verb. Hence we identify the verb occurring in the sentence as key to solving the problem of metaphor interpretation.

3.4 Knowledge Representation Issues in Verbs

We use the Paninian formalism (see Appendix A) to produce the initial parse. It is found out that it is the karaka role fillers which play the discriminating role in the same verb assuming different senses. Moreover, corresponding to its primary sense, the verb has some preferred karaka role fillers.

e.g. for the verb *pI* (drink)

the preferred karta would be a *prANI* (animate) and the preferred karma would be a *drava* (liquid).

This preference formalism helps in two ways.

1. Any input sentence where the karaka role filler(s) are not the preferred ones of the verb can be treated as a candidate for metaphor interpretation.

2. In such a case, the preferred karaka role filler(s) act as the source domain and the actual karaka role filler(s) act as the target domain and it can be explored as to what features of the source domain could be transferred to the target domain.

For example, in (14) the karta of pI (drink) is *gAdI* (vehicle) while the pre ferred karta of *pI* is *prANI* (animate). Hence the vehicle acts as the target domain while a living being acts as the source domain. Now what a metaphor interpretation system has to do is to find out that consumption of petrol by a vehicle is similar to drinking of a liquid by a living being.

This creates the need for making the verb entries in the lexicon richer in content by including information about the verb preferences. But that alone is not sufficient. What we aim at is to associate all such information with a verb so that the task of metaphor interpre tation can be accomplished by processing knowledge contained within that single verb entry in the lexicon.

3.4.1 What Other Knowledge is to be Included ?

Our guiding philosophy in finding an answer to this question is the definition of the verb itself which is the name of an action.

Every action

- has a result or *phala*, that is, the effect it has on the environment in which it occurs
- defines an activity which can be further subdivided into a complex of sub-activities
- has a (most probable) cause of occurrence
- has participants that participate in the action

In the Paninian formalism, the karakas provide a level of representation which is sufficient for producing a syntactic parse and a preliminary semantic representation of the input sentence from where onwards a deeper semantic and pragmatic analysis can be carried out. Chapter 4 describes how by representing the above discussed features of a verb-action we can encode some of the basic metaphors that suffuse human language.

The following example illustrates this fact.

(17) rAma pEsA KAtA hE
राम पैसा खाता है
Ram moneyeat
(Ram eats money)

In the above sentence, the verb *KA* (eat) has a *prANI* (animate) as its preferred karta and a *KAdya padArTa* (eatable) as its preferred karma.

The effect on karta	—	BUKa mitnA
		(removal of hunger)
The effect on karma	—	nigalA jAnA
		(get swallowed)
cause of occurrence	—	karta ko BUKa laganA
		(karta feeling hungry)
actual karta	—	rAma
actual karma	—	pEsA

Here the karaka assignment of karta and karma in the above sentence is provided by the Paninian parser.

The preference violation in the above sentence is in case of karma. Now *pEsA* (money) is viewed in terms of an edible object. The immediate inference drawn is that money removes Ram's hunger and that it gets swallowed by Ram in the process. Now a metaphor interpretation system can take

over from here and view hunger for food in source domain as desire for money in target domain and food being swallowed by Ram in source domain as money being embezzled by him.

In the above example it is clearly seen that it is the nature of the karaka role fillers that makes the vital difference in verb sense.

3.5 What is Meant by Metaphor Interpretation ?

In our framework, a metaphor would be deemed interpreted either if

(a) the system is able to give a suitable explanation for the metaphorical usage, or

(b) The system finds a suitable literal substitute for the metaphorically used word or phrase.

For example, in case of

(18) jamIna pAnI pItI hE
जमीन पानी पीती है
earth water drinks
(The earth drinks water)

First we see what all information we can gather about *pI* (drink)

(a) **Both Karta and karma are mandatory for** *pI*
(b) **Effect of verb-action on karta** : fulfilment of need of karta by karma
(c) **Effect of verb-action on karma** : assimilation within karta
(d) **Nature of karta** : inanimate
(e) **Nature of preferred karta** : animate
(f) **Nature of karma** : liquid
(g) **Nature of preferred karma** : liquid

Explanation It is the karta, in the above example, that causes a preference violation. It assimilates the karma and since the karta is inanimate, the action is passive. Hence we get the sense of passive assimilation.

Word Substitution The above found sense of passive assimilation can be given by a suitable word like (absorption). A suitable mechanism has to be devised to accomplish this task. Word substitution may not always be possible since it requires verbs/verb-phrases that are conceptually close to the given verb to be part of the system vocabulary.

3.6 Relationship between a Metaphorical Expression and its Equivalent Literal Expression

Listed below are some of the verbs and verb phrases which are the equivalent literal expressions of metaphors.

giranA	=	patana honA
(fall)		(decline)
KAnA	=	kama karanA
(eat)		(reduce)
pInA	=	soKanA
(drink)		(absorb)
pakadanA	=	garsta honA
(catch)		(get infected)

Now we explore what properties the left hand side and the right hand side expressions share and what are their properties that distinguish them.

A preliminary investigation reveals that

1. **AkAMkSA** (verb demand) with respect to mandatory karakas is same
2. The **effect** of the verbs/verb-phrases on their karaka role fillers is similar

Also some derived properties such as **volition** and **entropy** (discussed in Chapter 4) have similar values.

More importantly what is different about them is the nature of their karaka role fillers.

Combining all these properties of a verb/verb-phrase we come up with a measure of the conceptual closeness of the verbs. We take the stand that it is from among this set of conceptually close verbs that the suitable verb/verb-phrase explaining the metaphorical use is found.

3.7 Knowledge Representation Issues in Nouns

Our approach to the whole problem of metaphor interpretation is primarily verb centered. But not all shades of metaphors can be handled through this methodology. In some cases, like those of simile and metonymy, the underlying metaphor has to discovered by analyzing the nouns.

3.7.1 What Information is to be Included in the Noun Lexicon ?

As discussed earlier, the most important attribute about the noun is its nature. In the framework we propose, nature of the noun includes its type and the class to which it belongs.

For example, for the noun *gAdI*

Type = physical object (artificial)
Class = vehicle

3.7.2 Are Metaphors Culture Sensitive ?

Metaphor across different cultures :

Metaphors reflect the distinct culture in which a language exists. Conversely different cultures spawn different conceptual metaphors. For example, some of the metaphors on *money* in Hindi are :

(19) pEsA hAth kA mEla hE
पैसा हाथ का मैल है
money hand dirt
(money is the dirt on one's hand)

(20) pEse KAnA
पैसे खाना
money eat
(eat money = embezzle, cheat in money matters)

(21) pEsA KilAnA
पैसा खिलाना
money feed
(feed money = bribe)

It is obvious that in all these metaphors *money* is seen as something evil and contemptible. But in western culture attributing such notions to money should be unusual if not altogether impossible.

Depending on the culture, some objects (nouns) assume negative or positive connotations. In Indian culture, for instance, *pEsA* (money) has a negative notion while *dUdh* (milk) as in

(22) dUdh kI nadiyAz bahanA
दूध की नदियाँ बहना
milk rivers flow
(flow of rivers of milk)

(23 dUdh meM nahAnA
दूध में नहाना
milk bath
(bathe in milk)

has a positive notion.

Hence such nouns can be assigned a *culture code* having positive or negative value.

Most nouns are physical objects and their composition is one of their marked attribute. This along with the role they play in the real world and their salient features are incorporated in the knowledge associated with each noun. Since we wish to utilize as little knowledge as possible for metaphor interpretation, only such features are to be selected which could highlight some aspect of the noun when it is part of a metaphorical usage.

For example,

hATI (elephant) has the following salient features:

- bahuta motA hotA hE (is very fat)

- bahuta BArI hotA hE (is very heavy)
- lambI yAdASta hotI hE (has long memory)
- sUMda hotI hE (has a trunk)

3.8 Discussion

This chapter provides a framework in which metaphors in Hindi can be handled. Also, an analysis of the characteristics of metaphors that need to be captured by knowledge representation is presented. This analysis produced the following results :

- Such characteristic features of the verb are to be represented with which it can be associated.
- That some of the basic metaphors can be captured in these characteristic features
- Only those features of nouns to be included which can be highlighted in a metaphorical usage.

Chapter 4

Knowledge Representation

4.1 Introduction

Chapter 3 provided an analysis of the metaphor phenomenon and provided some requirements for the representation of metaphoric knowledge. This chapter describes exactly how this task is accomplished.

4.2 Representing Knowledge for Metaphor Interpretation

Chapter 3 provided an analysis of some of the characteristics exhibited by metaphors. In addition, a number of general suggestions were made for representations that might capture these characteristics. Also, since a word was treated as the unit of metaphor, knowledge was to be represented at the word level.

Keeping the above requirements in mind, we favor the frame-based organization of knowledge. Knowledge required for metaphor interpretation is organized into noun and verb frames. Each word frame contains lexical and semantic information about the word.

The knowledge representation scheme that is adopted has the following salient features:

1. Each verb frame contains information about the karaka requirements of the verb, the preferred role fillers, whether the preferred role fillers could play any metonymic role and the characteristic features of the verb that determine the nature of the verb.

2. Each noun frame contains lists of 3 elements which express a piece of functional or structural information and can be thought of as a complex semantic feature or property of a noun. Also contained in the noun frame is the information about the possible metonymic role the noun could play and about the type and class of the noun.

3. Most of the terms in the word frames are words with their own frames.

4. Since we have taken the stand that metaphors arise predominantly out of noun-noun or noun-verb interactions, we have not included word frames for adjectives, adverbs and other modifiers.

We have taken a unified approach to metaphor interpretation, which includes interpreting metonymy, similes and analogies. Hence the structure of the word frames has to be such that it contains enough information to tackle all these cases. Based on these considerations, the following structure is defined.

4.3 Structure of Verb Frame

The structure of the verb frame contains the following slots and fields.

1. Verb name
2. Karaka Information

   field 1 Karaka name

   field 2 Preferred filler for above

   field 3 Effect of verb on above

   field 4 Metonymic relation name (if applicable)

   field 5 identity

3. Cause of Verb (action)

   field 1 reason statement

   field 2 Associated karaka name

4. Characteristic features of the verb

   field 1 Verb demand

   - both karta and karma are mandatory
   - only karta is mandatory

   field 2 Volition

   - if action is intended by the karta
   - otherwise

   field 3 Entropy

   - degree of disorder increases
   - degree of disorder decreases
   - no change

   field 4 Effect on karta

   - positive effect (qualitative)
   - positive effect (quantitative)
   - negative effect (qualitative)
   - negative effect (quantitative)
   - no effect

   field 5 Effect on karma

   - positive effect (qualitative)
   - positive effect (quantitative)
   - negative effect (qualitative)
   - negative effect (quantitative)
   - no effect

Characteristic Features of Verbs (Intuitive Concepts)

Volition is a characteristic of the verb that states whether the verb-action takes plac as intended by the karta.

For example, in case of *uTa* (get up), *pI* (drink) and *KA* (eat) the verb-actio requires the will of the agent (karta) for the action to be completed. While i case of *gira* (fall), *baha* (flow) etc. the verb-action takes place without the will o the karta, and some extraneous cause may be responsible for the verb-action.

Entropy is a concept used here that has been borrowed from Physics and Chemistr which define entropy as the degree of disorder of a system. *It is important to note tha this concept of entropy is different from the way it is used in information theory and therefor it is not similar to Uncertainty.*

For example, in case *mila* (meet), *jura* (join) and *KA* (eat) the verb-action leads t increase in the order as in two entities coming together in *jura* and karma being assimilated by karta in *KA*. Hence these verb-actions lead to decrease in entropy. In case of *tUta* (break), *biCada* (part), and *biKara* (scatter) it is the other way round and the disorder of the system increases.

Effect on the Verb-Action on its karaka role fillers This field encodes some of the basic metaphors common to all languages and cultures in their most generalized form. In some manner we encode here the orientational metaphors as discussed by Lakoff and Johnson[8] like *up is good*, down is bad, more is up, happy is up, sad is down, in is good, out is bad and so on. Thus for *uTa*(get up), the effect of verb-action on its karta would be positive (qualitatively) and for *KA*, since the gains quantitatively by assimilating the karma, the effect would be positive (quantitatively).

Similarly, in case of *gira* (fall), the effect of verb-action on its karta would be negative (qualitatively) and for *pI*, since the karma is assimilated by the karta, the effect on the karma is negative (quantitatively). For some cases as in *cala* (walk) the effect of verb-action cannot be classified as negative or positive and is hence taken to be neutral.

field 6 Nature of karta

- animate
- inanimate and artificial
- inanimate but natural

field 7 Nature of karma

- animate
- inanimate and artificial
- inanimate but natural

4.4 Structure of Noun Frame

The structure of the noun frame contains the following slots and fields.

1. Noun name
2. Nature of the noun

   field 1 Type (jAwI)

   field 2 Origin (natural/artificial)

   field 3 Class (upAXi)

3. Culture code

   - positive
   - negative
   - neutral

4. Metonymic role played (if applicable)

   field 1 Relation name

   field 2 For : identity1, identity2, ...

5. Composition
6. Salient features

   field 1 Property1, Property2, ...

   field 2 salience value of each property

Unlike most previous approaches to metaphor interpretation, we do not organize our knowledge base consisting of verb and noun frames into any explicit hierarchy. Empirical results [10] have shown that any word hierarchy is quite bushy (depth is quite low). Moreover, since in our approach we are not adopting the approach of creating metaphor maps or feature matching across domains, the utility of static hierarchical representation is doubtful. Hence, we store the word frames in file format, the information contained in which can be referred to whenever needed without substantial overheads. Limited concept of hierarchy is embedded within noun frames but it is totally absent in case of verbs.

The knowledge representation scheme is illustrated by the following example. In

gAdI (vehicle)			
yaMwara (machine)	artificial	vAhana (vehicle)	
0			
part_for_whole	iMjana (engine)	pahiyA (wheel)	
ispAta			
ko iMjana	Sakti	detA hE	4
	tela	Kapata karatI hE	4
meM	yAtrI	bETate hEM	1
ko	calaka	calAtA hE	1

Figure 4.1: Noun Frame of gAdI.

(24) gAdI petrola pItI hE
गाड़ी पेट्रोल पीती है
vehicle petrol drinks
(The vehicle drinks petrol)

there are two nouns, the karta *gAdI* and the karma *petrola*, and a verb *pI*. Figs. 4.1, 4.2 and 4.3 show the word frames of each of them.

The variety of information contained in the verb frame is larger than that contained in noun frames. The most important information contained in the noun frames is the salient features of the noun. Associated with each salient feature is a salience value which is static. The sum total of all salience values is always ten and they mark the relative importance of each property in case of that noun being a part of a metaphorical usage.

In the example considered above, the underlying metaphor involved is

pInA = *aDika Kapata karanA*

(drink) (excessive consumption)

Fig. 4.3 shows the frame representation of the source domain *pI*. It states that pInA is a verb that takes at least two karakas, karta and karma, and also states preferences for both. The preferred karta for *pI* is of type *prANI* (animate) and the preferred karma is of type *drava* (liquid). The karta usually plays no metonymic role whereas the karma drava does play one, that of content in the container for content relation. Also stated are the effect of verb-action on both karakas and the most probable reason for its occurrence. The last field contains a list of characteristic features of the verb in coded form. The seven numbers code the following information :

1. **both karta and karma are mandatory**
2. **the verb is volitional**
   (Since the intention of karta is involved in the verb-action)

petrola (petrol)			
drava (liquid)	natural	wela (oil)	
0			
none			
petrola (petrol)			
vAhana kA	iMXana	hotA hE	4
	UrjA	detA hE	3
	iMjana dvArA	Kapata hotA hE	3

Figure 4.2: Noun Frame of petrola.

pI (drink)				
karta	prANI (animate)	pyAsa ko buJAnA (quench thirst)	none	
karma	drava (liquid)	Kapawa karanA (consume)	container_for_content	content
pyAsa lagnA (feel thirsty)	karta			
2 1 2 3 4 3 1				

Figure 4.3: Verb Frame of pI.

Kapata_kar (consume)			
karta	BOwika-others (physicsl object)	jarUrata ko pUrI karanA (fulfils a need)	none
karma	BOwika_others (physical object)	istemAla honA (get used up)	none
jarUrata honA (feel need of)	karta		
2 1 2 3 4 1 0			

Figure 4.4: Verb Frame of Kapata_kara.

3. **the entropy decreases as a result of verb-action**
   (Since karma is assimilated by karta it vanishes as a result of verb-action and hence leads to decrease in the degree of disorder of the environment in which the verb-action occurs)

4. **the effect on karta is positive (quantitatively)**
   (verb-action fulfils a basic need of karta. The karta gains quantitatively as it assimilates the karma)

5. **the effect on karma is negative (quantitatively)**
   (karma gets assimilated by the karta and it ceases to exist its original form)

6. **the preferred karta is animate**

7. **the preferred karma is inanimate but natural**

The last field, characteristic feature array, contains the symbolic information present in rest of the verb frame in its most generalized form. Also, some of the most basic metaphors are embedded in it. Most importantly, the characteristic feature array provides a conceptual ground for comparing verbs and verb-phrases which is central to our approach of verb substitution for metaphor interpretation.

Fig. 4.4 shows the frame representation for the target domain *Kapawa_kara*.

Comparing the characteristic feature array of both the source domain pI and the target domain Kapata_kar we find that, but for the last two subfields, all the sub-fields match. Now the last two sub-fields contain information about the nature of the karaka role fillers of the verb. Therefore, this is in accordance with our earlier hypothesis that it is the semantic environment of the verb, consisting of its karaka role fillers, that plays a crucial role in a verb acquiring a particular sense. Also that the conceptual closeness of any two verbs is directly proportional to the degree of similarity of the characteristic feature array. This is critical to accomplishing the task of metaphor interpretation.

4.5 Conclusion

This chapter introduced the mechanism for representing knowledge for metaphor interpretation. In particular noun frames and verb frames. Unlike most other approaches, the knowledge contained in the word frames is not **raw** but to a certain degree it is **pre-processed**. This greatly helps in limiting the amount of knowledge that is hard-coded in the system.

Chapter 5

Metaphoric Interpretation

5.1 Introduction

This chapter demonstrates how the knowledge framework described in the previous chapter can be applied to interpret metaphoric language. The basic premise is that literal and metaphorical meaning are two ends of the same scale but the literal is basic and the metaphorical derived.

5.2 Metaphor Interpretation

The approach to metaphor interpretation discussed here involves three stages :

(a) Recognition,

(b) Classification, and

(c) Comprehension.

5.2.1 Recognition

We have two kinds of metaphors, one in which the identity is context free because it exhibits linguistic deviation and the other in which only the discourse context reveals the figurativeness. Metaphor of the first kind would be established if it exhibits semantic deviation in the sentence. If the linguistic context does not reveal the domain incongruence, the pragmatic situation will do so in the case of the second kind.

First kind

For example,

(25) bacce to bandara hote hEM
बच्चे तो बंदर होते हैं
children monkey are
(Children are monkeys).

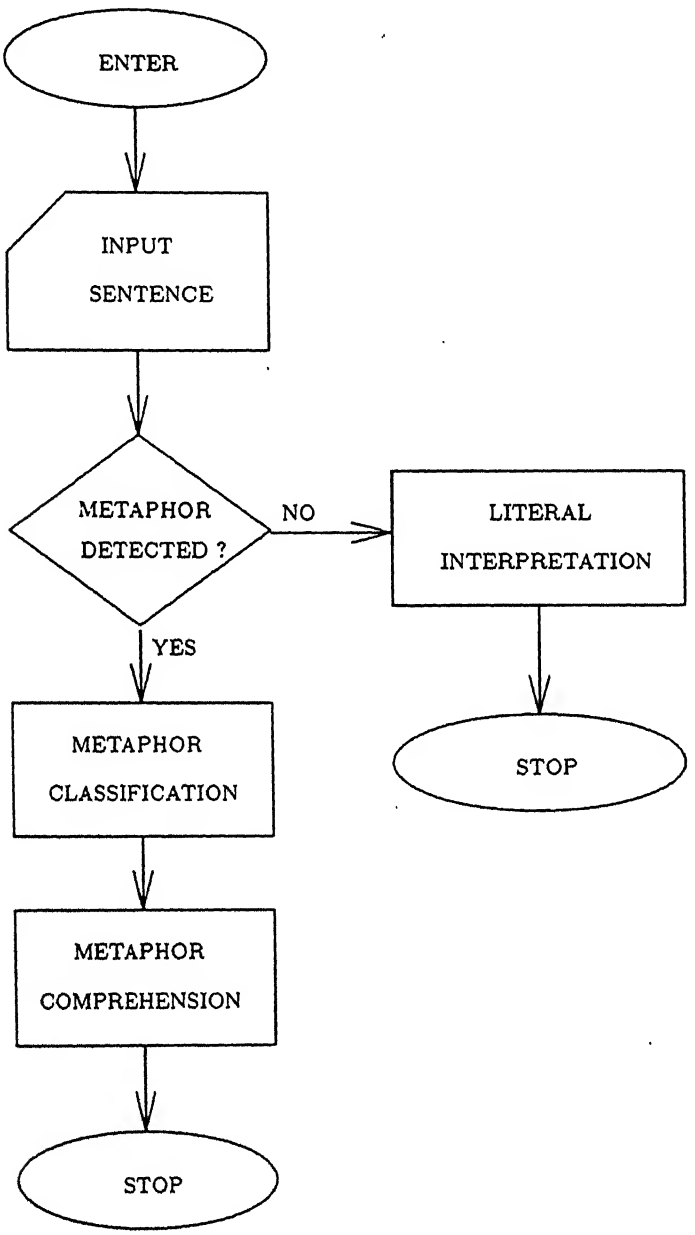

Figure 5.1: Flow Diagram for Metaphor Interpretation

Second kind

For example,

(26) sUradAsa kiAzKe saMsAra ki vastaviktA ko deKa sakatI TI
सूरदास की आँखे संसार की वास्तविकता को देख सकती थी
Surdas eyes world reality see can
(Surdas had eyes that could see the reality of the world).

In our model we deal with only the metaphors of the first kind since we restrict ourselves to sentence level analysis. Our model deliberately avoids the unrestricted use of contextual information, since we believe that at least some sentence meaning is independent of context. The karaka assignment by the Paninian parser contains part of the primary content of an utterance and this primary content represents the meaning of an utterance that is derivable from knowlegde of the conventions of Hindi language, independent of context.

In light of the above facts, our metaphor interpretation system primarily relies on the selection restrictions violations to detect a metaphorical usage. The main problem with the selection restriction violation approach is that perfectly well formed sentences exist that have a metaphorical interpretation and yet contain no selection restriction violations. What we found out that most of such cases (exceptions can surely be there) are instances of simile or negative analogy. Such cases are recognized by examining the surface features of the sentence since structure of such sentences is rather simple.

For example,

(27) rAma jAnavara hE
राम जानवर है
Ram animal is
(Ram is an animal)

The above sentence is an instance of simile.

(28) rAma koI Beda bakarI nahiM hE
राम कोई भेड-बकरी नही है
Ram cattle not
(Ram is not a cattle)

The above sentence is an instance of negative analogy.

Algorithm for Metaphor Recognition

Based on the above discussion, the algorithm for recognizing a metaphor and to distinguish a metaphor from an anomaly is formulated as given below.

step 1 Input sentence to the Paninian parser.

step 2 If *AkAMkaSA* (demand) of the verb is greater than or less than the number of source words available, then the sentence is anamolous.

step 3 A sentence is considered as a candidate for metaphorical interpretation if

- *AkAMkaSA* (demand) of the verb is equal to the number of source words available and there are violated preferences.
- The examination of surface features of the sentence reveal an instance of a simile.

step 4 Else, the sentence is considered to have no metaphorical usage in it.

5.2.2 Classification

As stated in chapter 3, we consider similes, analogies, metonymies and metaphors to be special cases of a more general phenomenon, referred to as metaphor for convenience, and handle all under a common operational framework.

Each of the above mentioned cases has certain distinct linguistic and conceptual features associated with it. The interpretation process is designed to take this into account and follows different procedures to adequately handle each of the above cases along with other shades of metaphors.

The computational model of metaphor interpretation presented here considers interaction among different sentence units as key to the process of metaphor generation. Therefore we group metaphors into two basic categories based on the interaction of different sentence units.

Arising out of Noun-Noun Interaction

This category includes metaphors that can interpreted by processing knowledge contained in the noun frames. Verb knowledge plays no part in the interpretation process.

(a) Simile

Simile is an explicit statement of resemblance between two terms, both of which are nouns. For example

(29) rAma hAtI hE
राम हाथी है
Ram elephant is
(Ram is an elephant)

(30) rAma to gadA hE
राम तो गधा है
Ram ass is
(Ram is an ass)

As in the above examples, similes contains two noun terms preceeding the verb root *hE* (is).

In (29), the second term *hATI* (elephant) transforms our view of the first term rAma (human being) by transferring its features to the second term. Similar is the case in (30).

Arising out of Noun-Verb Interaction

This category includes metaphors which require knowledge contained in both the noun and verb frames for interpretation.

i. **Verb Centered** Verb centered metaphors are those that change a noun term(s) only implicitly and the underlying metaphor is centered in the verb. For this reason, sometimes merely substituting the verb comprising the metaphorical usage by suitable verb/verb-phrase accomplishes the interpretation task.

- **Physical Domain**
  In this sub-category, all the karaka role fillers, belong and refer to the physical world.
  For example

  (31) AsamAna ro raha hE
  आसमान रो रहा है
  sky cry
  (Sky is crying)

  (32) rAma ne bUKAra pakada liyA
  राम ने बुखार पकड़ लिया
  Ram fever catch
  (Ram has caught fever)

- **Mental Domain**
  This sub-category includes metaphors that refer to emotions or state of mind.
  For example

  (33) rAma kA dila tUta gayA
  राम का दिल टूट गया
  Ram's heart break
  (Ram's heart broke)

  (34) rAma kAmanagirA huA hE
  राम का मन गिरा हुआ है
  Ram's mind fall
  (Ram's mind is fallen)

  In most metaphors that are in the mental domain, either the karta or the karma of the verb is *prANI_aMga* (part of body). Depending on the effect of the verb on its preferred karakas, the state of mind can be described in positive or negative terms.

ii. **Noun Centered**
In this case, the metaphor interpretation involves expanding the noun term or its replacement by another related term and therefore the noun term(s) is changed explicitly.

- **Metonymy**
  Metonymy involves "using one entity to refer to another that is related to it" [13].

We organize instances of metonymy into the following six categories.

A. **Part for Whole** (synecdoche)

For example,

(35) nirdeSaka ko naye cehare kI talASa hE
निर्देशक को नये चेहरे की तलाश है
director new face search
(The director is in search of new faces)

B. **Container for Content**

For example,

(36) rAma gilAsa pI gayA
राम गिलास पी गया
Ram glass drink
(Ram drank the glass)

C. **Producer for Product**

For example,

(37) rAma ne nayI mAruti KarIdI hE
राम ने नयी मारुति खरीदी है
Ram new maruti buy
(Ram has bought a new maruti)

D. **Object used for User**

For example,

(38) Aja basoM kI hadatAla hE
आज बसों की हड़ताल है
today buses strike
(The buses are on strike today)

E. **Artist for Art form**

For example,

(39) rAma premacMda paDatA hE
राम प्रेमचंद पढ़ता है
Ram Premchand read
(Ram reads Premchand)

F. **Property for Whole**

For example,

(40) dakSina aPrIkA meM aSveta honA aBiSApa hE
दक्षिण अफ्रीका में अश्वेत होना अभिशाप है
South Africa non-white curse
(It is a curse to be a non-white in South Africa)

The analysis of metonymy would involve the following steps:

- to identify the incompatible term in the sentence
- to find the term that will combine with the 'incompatible' term and yield the literal statement.

Algorithm for Metaphor Classification

step 1 If the only verb present is *hE* with two nouns preceeding it, then the metaphor encountered is a **simile.**

step 2 If any karaka that fails to match the preferred karaka of the verb can play a metonymic role and the corresponding filler (after cross checking with the noun frame of the filler) leads to removal of semantic tension, then the metaphor is **metonymic.**

step 3 If the verb has a single mandatory karaka requirement and its karta fails to match the preferred karta of the verb and it is in the class *prANI_aMga* (part of body), then the metaphor is **verb-centered (mental domain).** In case the verb has a requirement of more than one karaka, it is the karma that has to fulfil all the above conditions instead of karta.

step 4) Else, the metaphor is treated as **verb-centered (physical domain)**

5.2.3 Comprehension

Conceptual Analysis

The interpretation of sentences containing metaphoric language is a two step process. In the first step, a syntactic parse and a preliminary semantic representation are produced. In te second step, this preliminary representation is replaced by the most specific set of concepts that can coherently explain the input. For practical purposes, our model limits the application of metaphor interpretation techniques to single sentence utterances only.

Initial Parse

The paninian parser for Hindi developed at IIT Kanpur provides the karaka assignment for the demand word, that is, verb. The metaphor interpretation system takes off from the karaka level which is a level somewhere inbetween the syntactic and the semantic levels. All the selectional restrictions in the parser are relaxed so that the parser uses no semantic information to guide the parse and makes no effort to resolve syntactic ambiguities.

Extension to Paninian Parser

The Paninian parser at IIT Kanpur was modified to handle the **kriya moola** phenomenon. Kriya moolas or conjunct verbs are sequences of nouns or adjectives plus a verb, which are viewed semantically as units functioning as verbs.

The following examples illustrate the kriya moola phenomenon.

(41) jiMdagI ne rAma ko DokA diyA hE
ज़िंदगी ने राम को धोखा दिया है
life Ram betray
(Life has betrayed Ram)

	word root		word root
karta :	baccA (child)	karta	rAma (Ram)
karma :	Pala (fruit)	karma	pEsA (money)
verb :	KA (eat)		KA (eat)

Figure 5.2: Primary Parse.

(42) rAma ke dimAga meM jaMga lagA hE
राम के दिमाग में जंग लगा है
Ram brain rust attach
(Ram's brain is rusted)

In the above examples, the underlined sentence units are the kriya moolas. Since kriya moolas behave semantically as verbs, their karaka requirements need to be satisfied. But since the karaka requirements of kriya moola are not the same as that of verb involved in it, the karaka chart of the verb involved is transformed appropriately depending on the noun or adjective present to obtain the karaka chart of the kriya moola. Now a sentence involving a kriya moola is handled like any other sentence.

Consider the following examples

(43) baccA Pala KAtA hE
बच्चा फल खाता है
child fruit eat
(The child eats a fruit)

(44) rAma pEsA KAtA hE
राम पैसा खाता है
Ram money eat
(Ram eats money)

The primary parse representations from these examples as provided by the Paninian parser are given in Fig. 5.2

This representation has simply assigned karaka roles to the nouns corresponding to the verb demand and no constraint checking is done on the karaka role fillers.

The similarity between the primary parse representations of these two sentences reflects the similarity in their surface forms. The following interpretation process will take these primary forms and produce two very different final interpretations.

Interpretation Process

As discussed in chapter 3, the interpretation process seeks to either

- explain the metaphorical usage, or
- find a proper word/phrase substitute giving the literal meaning.

Consider example (43) again. The preferred karta of verb *KA* is animate and its preferred karma is an eatable. Both these conditions are satisfied by *baccA* and *Pala* respectively. Hence there is no preference violation and the sentence yields no metaphorical interpretation. The verb *KA* takes its default sense, that is, of eating as shown below.

Interpreting sentence : rAma Pala KAtA hE

Preferred KarwA condition satisfied

Preferred Karma condition satisfied

No Metaphorical Usage Detected.

Interpreting as: rAma Pala KAtA hE (literal interpretation)

In case of example (44), there is a preference violation as *pEsA* is not the preferred karma of *KA*. This causes *pEsA* to be viewed as an eatable. The final interpretation is as shown below.

Interpreting sentence : rAma pEsA KAtA hE

Preferred KarwA condition satisfied

Preference Violation in case of karma

Metaphorical Usage Detected.

Category : VERB CENTERED (Physical Domain)

Interpretation at Level 1 :

Here the karma pEsA is being viewed as a KAdya padArTa

(Here the karma money is being viewed as an eatable)
Interpretation at Level 2 :

pEsA KA is equivalent to pEsA nigalA jAnA

(eat money) (swallow money)

Interpretation at Level 3 : (Explanatory Mode)

rAma dvArA pEsA kama karanA with negative intention

(Money being reduced by Ram with negative intention)

Interpretation at Level 3 : (Verb Substitution Mode)

Searching for conceptually close words ...

Evaluating **pI** **Kapata_kara** **hadapa** for constraint satisfaction

Discarding **pI** **Kapata_kara**

Verb Substitution successful : **hadapa** for **KA**

Interpretation Algorithm

This section presents the basic interpretation algorithm. The most important point to realize about the strategy embodied in this algorithm is that how the interpretation process follows different procedures to handle each class of metaphor while operating on the same knowledge framework.

Step 1 If the metaphor belongs to the class SIMILE, the second noun term (target domain) is replaced by the salient feature in its noun frame that has the highest salience value.

Step 2 If the metaphor belongs to the class METONYMY, the corresponding metonymic relation is used to extend the noun term that constitutes it so that the semantic deviation encountered earlier vanishes.

Step 3 If the metaphor belongs to the class VERB CENTERED (mental domain), the effect of the verb-action on the karaka that is in the class prANI_aMga (part of body) is examined. A positive effect corresponds to a positive state of mind (or emotion) and a negative effect coresponds to a negative state of mind (or emotion).

Step 4 If the metaphor belongs to the class VERB CENTERED (physical domain), the interpretation process proceeds through three stages.

Stage 1 : The karaka that causes the preference violation is viewed in terms of the corresponding preferred karaka of the verb.

Stage 2 : The verb is viewed in terms of its effect on the karaka that causes the preference violation. Those noun terms in the verb effect field of the verb frame that have type conflict with the karta are discarded. Wherever the conflict is due to mismatch

of the **origin** field in the noun frame, the composition of the noun term replaces the noun term. The culture code associated with the noun term and the volition of the verb are also evaluated to check for constraint satisfaction and suitablity of the various possible interpretations. If the interpretation process fails at this point, then the **cause of action** field in the verb frame is analyzed.

Stage 3(a) : If the interpretation process is in the explanation mode, then it tries to find a path which leads to one of the salient features in the noun frame of the karaka that caused the preference violation. If successful, this salient feature replaces the verb in the input sentence to give the correct interpretation of the metaphorical usage.

Stage 3(b) : In the verb substitution mode, the feature array of the verb is transformed to yield another feature array with the desired field values. All verbs/verb-phrases whose feature arrays match with this transformed feature array are selected for evaluation. Only those verbs/verb-phrases that satisfy all the semantic constraints of the input sentence are treated as verb substitutes that could possibly give a literal equivalent of the metaphorical usage.

The steps of the algorithm and some of the issues raised by the strategy it embodies will now be illustrated in terms of the processing of the following examples. One examples is taken from all the different classes of metaphors as discussed in the classification scheme.

(45) rAma hAtI hE
राम हाथी है
Ram elephant
(Ram is an elephant)

(46) rAma ne gilAsa pI liyA
राम ने गिलास पी लिया
Ram glass drink
(Ram drank the glass)

(47) rAma kA dila tUta gayA
राम का दिल टूट गया
Ram's heart break
(Ram's heart broke)

(48)AsamAna ro raha hE
आसमान रो रहा है
sky cry
(Sky is crying)

For each of these examples, the system directly applies knowledge contained in the relevant word frames which allows the sentence to be interpreted correctly. Consider the processing of example (45), which is an instance of simile. The interpretation process for similes is quite straightforward.

Interpreting sentence : rAma hAtI hE

Metaphorical Usage Detected.

Category : SIMILE

Interpreting as: rAma bahuta motA hE

(Ram is obese)

Other interpretations possible are :

rAma bahuta BArI hE

(Ram is very heavy)

rAma kI lambI yAdASta hE

(Ram has a good memory)

rAma kI sUMda hE

(Ram has a trunk)

In the above case, all the system does is to analyze the salient featues of the target term (*hAtI*) and substitute the term by the noun property that has the highest salience value. Other possible interpretations are also listed containing other properties of the noun in the decreasing order of their salience value.

Example (46) is an instance of metonymy. In this case whichever karaka causes preference violation is examined to see if it is playing any metonymic role. If there is a entry for the possible metonymic relation in the verb frame, then the noun term is expanded in accordance with that relation. Else, each metonymic relation discussed in previous section is applied in the order mentioned starting with **Part for Whole** relation. If any of the relation correctly explains the metonymic use, the noun term which is part of the metonymic usage is expanded to yield the final interpretation.

Interpreting sentence : kisAna ne gilAsa pI liyA

Preferred KarwA condition satisfied

Preference Violation in case of karma

Metaphorical Usage detected.

Category : METONYMY

Metonymic relation : container_for_content

Metonymic relation satisfied.

Interpreting as: Here gilAsa stands for gilAsa meM drava

The metonymic relations **Part for Whole** and **Container for Content** are source driven while rest of the relations discussed earlier are target driven [4]. For example, the interpretation process peoceeds from the part in the Part for Whole realtion and finally finds the corresponding whole. This is because a part has a fewer wholes than the number of parts a whole can have. It is the other way round for the target driven metonymic relations. For example, in **Container for Contents**, the epistemological nature of containers and contents is that the containers generally mentioned in **Container for Content** metonymies are artifacts designed for the function of containing — hence one can usually find quite specific information about the typical contents of a certain container — whereas contents do not generally have the function of being contents of something. hence it makes sense to drive inferencing from the container towards the contents.

The example(47), belongs to the category of verb centered metaphors in mental domain. Such metaphors invariably refer to an emotion or a state of mind. Though our system cannot describe that state of mind in precise terms, it can distinguish between negative and positive state of mind. The system checks the effect of the verb on the relevant karaka. A negative effect corresponds to a negative state of mind while a positive effect corresponds to a positive state of mind. In the above case, since the verb *tUta* (break) has a negative effect on its karta it refers to a negative state of mind and therefore some possible interpretations are given.

Interpreting sentence : rAma kA dila tUta gayA

Preference Violation in case of karta

Metaphorical Usage Detected.

Category : VERB CENTERED (mental domain)

Effect of verb on karta : negative

Interpreting as : This refers to a negative state of mind

Possible interpretations for dila tUta :

heart break

duKI honA

(become sad)

pIdA honA

(feel pain)

sadamA laganA

(get shocked)

In all the previous examples the metaphor interpretation process was relatively simple. The real potential of the system is only visible when interpreting example (48).

This sentence is an instance of verb centered metaphor in physical domain. At the first level of interpretation, the karta *AsamAna* (sky) is viewed as a *prANI* (animate), the preferred karta of the verb *ro* (cry).

At the second level of interpretation, the effect of verb ro on its karta (*AzKa se Azsu bahanA*) (tears flowing from the eyes) is analyzed. First, the noun *AzKa* (eye)'s word frame is loaded for processing. There is a type mismatch with *AsamAna* since *AzKa* is a part of body while *AsamAna* is a physical entity. Hence *AzKa* is discarded. Next the word frame of noun *Azsu* is loaded. In this case there is a type match. Then the composition field of *Azsu* is examined which gives that primary component of *Azsu* is *pAnI* (water). Hence *pAnI* is substituted for *Azsu* (tears). So at second level the interpretation is that *AsamAna ro* (sky crying) is equivalent to *AsamAna se pAnI bahanA* (water flowing from sky).

At the third level, the salient feature list of the noun frame of karta is examined for a term whose composition is also *pAnI*. This is satisfied by *bAriSa* (rain) which is a noun term in one of the salient properties of *ASamAna*, i.e., *AsamAna se bAriSa hotI hE*. Hence this interpretation is flagged off as the final one.

The verb substitution approach does not succeed in this case.

Interpreting sentence : AsamAna ro rahA hE

Preference Violation in case of karta

Metaphorical Usage Detected.

Category : VERB CENTERED (Physical Domain)

Interpretation at Level 1 :

Here the karta AsamAna is being viewed as a prANI

Interpretation at Level 2 :

AsamAna ro is equivalent to AsamAna se pAnI bahanA

(sky crying) (water flowing from sky)

Interpretation at Level 3 : (Explanatory Mode)

AsamAna se bAriSa hotI hE

(It rains from the sky)

Interpretation at Level 3 : (Verb Substitution Mode)

Searching for conceptually close words ...

Search Unsuccessful.

To illustrarte the verb substitution methodology, again consider the example

(49) rAma pEsA KAtA hE
राम पैसा खाता है
Ram moneyeat
(Ram eats money)

In this case, the feature array of the verb *KA* is shown in the figure 5.3.

2	1	2	3	4	3	1

Figure 5.3: Feature Array of verb KA.

The preference violation is due to the karma *pEsA*. Hence the transformed feature array becomes as shown in Fig. 5.4.

2	1	2	3	4	3	0

Figure 5.4: Transformed Feature Array of verb KA.

Since the last two fields of the feature array define the nature of the karakas, this transformed feature array is matched against feature arrays of other verbs/verb-phrases for the first five

fields. For the verb *KA*, this results in the following verbs/verb-phrases having successful matches.

(1) pI (2) Kapata_kara (3) hadapa

The feature arrays of each are shown in Figs. 5.5, 5.6 and 5.7.

2	1	2	3	4	3	1

Figure 5.5: Feature Array of verb pI.

2	1	2	3	4	1	0

Figure 5.6: Feature Array of verb Kapata_kara.

2	1	2	3	4	3	0

Figure 5.7: Feature Array of verb hadapa.

Among these, only hadapa satisfies all the constraints and results in a valid interpretation.

5.3 Summary

The main thrust of this approach to metaphor interpretation is the application of knowledge related to the preferred or primary sense of a word to derive the metaphorical meaning. The initial parse of a sentence produces a primary representation that is essentially a set of constraints on the final representation derived from the lexicon and language concepts. The main task of the interpretation process is to find an interpretation of the input that is coherent with the constraints posed by this primary representation.

Chapter 6

SUMMARY AND CONCLUSIONS

6.1 Introduction

The basis for this thesis is the cognitive and practical motivation for the development of knowledge representation framework for metaphor interpretation. This foundation has been realized in the representation framework discussed in chapter 4, which utilizes methods in linguistic and conceptual representation to synthesize a uniform representation applicable to the metaphor interpretation task. The approach taken is knowledge-based but not knowledge intensive since it does make use of any substantial amounts of explicit knowledge about the metaphors in the language. Our approach has achieved the following two results: it is possible to capture systematic knowledge for metaphor interpretation using straightforward knowledge representation techniques, and this knowledge can be efficiently applied to interpret metaphoric language.

The practical and theoretical results of this work have two areas of impact:

(a) the increased understanding of representational and processing aspects of metaphor interpretation, and

(b) the suggestion of areas in which the work can be further explored.

The first area above supplies some immediate positive feedback, in the perception of improvements in a system. The second area, however, is perhaps most important in this type of work. It is safe to admit that most aspects of the interpretation of metaphors in Hindi language have not been solved and to assert that many can be productively explored. Thus the work presented here is geared towards speeding the evolution of Hindi metaphor interpretation systems by presenting a framework within which further research can be conducted.

6.2 Summary

The approach described in this thesis suggests that the problem of metaphor interpretation be attacked from a broad perspective.

The practical problem addressed is that of building metaphor interpretation system with a parsimonious knowledge representation scheme. Parsimony of representation is significant since it indicates that the approach has been able to exploit generalizations, a facility which also makes a knowledge base easier to adapt and extend.

This approach has the the following salient points.

- Every word has a primary or preferred sense associated with it.
- It is the semantic environment which governs what sense a word takes.
- The word sense is a function of certain charactristic features associated with the word.
- The semantic environment acts as a transformation function acting on the charateristic features defining the primary sense of the word therby giving rise to the secondary word senses.
- Metaphors, metonymies, similes and related phenomenon can be handled under a common operational framework.

6.3 Directions for Further Research

This work has concentrated on some representational and tactical aspects of metaphor interpretation. Two areas for future related research that have particular promise are the study of context and of knowledge acquisition. Both pose extremely difficult theoretical and practical problems.

6.3.1 Context Sensitivity

The problem of context senstivity is fundamental for interpretors which are to be used with knowledge about different users, domains, and situations. The metaphor interpretation system in its present form does not make use of any contextual information for interpreting metaphors. In our knowledge representation scheme every salient feature in the noun frame, describing the role that noun plays in real world and its prominent properties that could be highlighted in a metaphorical usage, has a salience value associated with it denoting its relative likelihood of being highlighted in a metaphorical usage involving that noun term. The salience, which can be assigned to a domain at the time it is defined, is static since it does not take into account ehe termed shift of focus as a result of changing context. A higher level system can be designed to keep track of the context and determine salience based upon it.

This dynamic salience can be made to override the static salience or some weighted means can be computed of static and dynamic saliences. This update can be carried out periodically to incorporate the shift in salience as a result of changing context.

6.3.2 Feature Array

The feature array which is a mathematical abstraction of all the characteristic features of a verb has only seven attribute fields. When used for interpreting metaphors by verb substitution, it may not work well for large vocabularies. To increase its efficacy, more characteristic features of a verb have to be discovered.

6.3.3 Knowledge Acquisition

The problem of acquisition is critical because it is hard to believe that true robustness can be achieved without automated methods for adding knowledge to a system. The present implementation of the metaphor interpretation system can be enhanced so that it can not only interpret metaphors but also update the domain knowledge dynamically.

6.4 Conclusions

The immediate positive results presented here are the improved handling of phenomena which were difficult for previous systems, the ease with which a sampling of linguistic and conceptual knowledge is represented, and the applicability of a simple, efficient, interpretation mechanism making use of this knowledge.

The computational model discussed in this thesis was developed for handling metaphor and related phenomena in Hindi but it is valid for all languages to which Paninian formalism is applicable. Hence it is valid for almost all Indian languages. Moreover, the conceptual ground of the theory proposed is quite broad and it could as well be extended to be applicable to English and other languages in the West.

Appendix A

Paninian Formalism

A.1 Paninian Model

The Paninian model uses the notion of karaka relations, which are syntactico-semantic (or semantico-syntactic) relations between the verbals and other related constituents in a sentence. They by themselves do not give the semantics. Instead they specify relations which mediate between vibhakti of nominals and verb forms on one hand and semantic relations on the other (Kiparsky, 1982). Two of the important karakas are karta karaka and karma karaka. Frequently, the karta karaka maps to agent theta role, and the karma to theme or patient theta role.

As part of this framework, a mapping is specified between karaka relations and vibhakti (which covers collectively case endings, post-positional markers, etc.). This mapping between karakas and vibhakti depends on the verb and its tense aspect modality (TAM) label. The mapping is represented by two structures: default karaka charts and karaka chart transformations. The default karaka chart for a verb or a class of verbs gives the mapping for the TAM label called basic. It specifies the vibhakti permitted for the applicable karaka relations for a verb when the verb has the basic TAM label. For other TAM labels there are karaka chart transformation rules. Thus, for a given verb with some TAM label, appropriate karaka chart can be obtained using its basic karaka chart and the transformation rule depending on its TAM label.

In Hindi for instance, the basic TAM label is tA_hE (which roughly stands for the present indefinite but is purely syntactic in nature). The default karaka chart for two of the karakas is given in Fig. 1. This explains the vibhakti in sentence A.1. where 'Ram' is karta and 'Pala' (fruit) is karma, because of their vibhakti markers ϕ and ko, respectively.

A.1 rAma Pala ko KAtA hE.

KARAKA	VIBHAKTI	PRESENCE
Karta	ϕ	mandatory
Karma	ko or ϕ	mandatory
Karana	se or dvArA	optional

Fig. 1: A default karaka Chart

TAM LABEL	TRANSFORMED VIBHAKTI FOR KARTA
yA	ne
nA_padA	ko
yA_gayA	se or dvArA (and karta is optional)

Fig. 2: Transformation rules

```
Ram   fruit  -ko   eats   is
(Ram eats the fruit.)
```

Fig. 2 gives some transformation rules for the default mapping for Hindi. It explains the vibhakti in sentences A.2 to A.4, where Ram is the karta but has different vibhaktis, ne, ko, se, respectively. In each of the sentences, if we transform the karaka chart of Fig. 1 by the transformation rules of Fig. 2, we get the desired vibhakti for the karta Ram.

```
A.2  rAma   ne   Pala   KAyA.

     Ram   -ne  fruit   ate
     (Ram ate the fruit.)

A.3  rAma   ko   Pala   KAnA   padA.

     Ram  -ko    fruit  eat    had to
     (Ram had to eat the fruit.)

A.4  rAma   se  Pala   nahI   KAyA   gayA

     Ram  -se   fruit  not    eat     could
     (Ram could not eat the fruit.)
```

In general, the transformations affect not only the vibhakti of karta but also that of other karakas. They also 'delete' karaka roles at times, that is, the 'deleted' karaka roles must not occur in the sentence.

A.2 Complex Sentences

A major support for the theory comes from complex sentences, that is, sentences containing more than one verb group. We first introduce the problem and then describe how the theory provides an answer.

Consider the Hindi sentence A.5. In A.5, Ram is the karta of both the verbs: KA (eat) and bulA (call). However, it occurs only once. The problem is to identify which verb will control its vibhakti.

TAM LABEL	TRANSFORMATION
kara	Karta must not be present. Karma is optional.
nA	Karta and karma are optional.
tA_huA	Karta must not be present. Karma is optional.

Fig. 3: More transformation rules

A.5 rAma Pala KAkara mohana ko bulAtA hE.

Ram fruit having-eaten Mohan -ko calls is
(Having eaten fruit, Ram calls Mohan.)

The observation that the matrix verb rather than the intermediate verb controls the vibhakti of the shared nominal is true in the above sentences. The theory we will outline to elaborate on this theme will have two parts. The first part gives the karaka to vibhakti mapping as usual, the second part identifies shared karakas.

The first part is in terms of the karaka vibhakti mapping described earlier, only the intermediate verbs have their own TAM labels. Hence it is handled by exactly the same mechanism. For example, kara is the TAM label [1] of the intermediate verb group KA (eat) in A.5. As usual, these TAM labels have transformation rules that operate and modify the default karaka chart. In particular, the transformation rules for three of the TAM labels (kara and nA) are given in Fig. 3. The transformation rule with kara in Fig. 3 says that karta of the verb with TAM label kara must not be present in the sentence and the karma is optionally present.

By these rules, the intermediate verb KA (eat) in A.5 does not have (independent) karta karaka present in the sentence. Ram is the karta of the matrix or the main verb. Pala (fruit) is the karma of KA. This is accommodated by the above transformation rule for 'kara'.

In the second part, there are rules for obtaining the shared karakas. Karta of the intermediate verb KA in A.5 can be obtained by a sharing rule of the kind given by S1. **Rule S1:** Karta

of a verb with TAM label 'kara' is the same as the karta of the verb it modifies. [2]
The sharing rule(s) are applied after the tentative karaka assignment (using karaka to vibhakti mapping) is over. In the present example, karta of KA (eat) is rAma, same as that of main verb bulA (call).

A.3 Constraint Based Parsing

The Paninian theory outlined above can be used for building a parser. First stage of the parser takes care of morphology. In the next stage local word grouping takes place, in which based on local information certain words are grouped together yielding noun groups and verb groups. These involve grouping post-positional markers with nouns, auxiliaries with main verbs etc.

[1] Roughly meaning 'having completed the activity'. But note that TAM labels are purely syntactic, hence the meaning is not required by the system.
[2] which in the present sentence is the main verb.

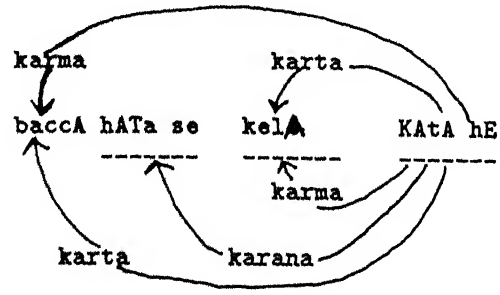

Fig. 4: Constraint graph

Rules for local word grouping are given by finite state machines. Finally, the karaka relations among the elements are identified in the last stage called the *core parser*.

Given the local word groups in a sentence, the task of the core parser is two-fold: (a) To identify karaka relations among word groups, and (b) To identify senses of words. The first task requires karaka charts and transformation rules. The second task requires lakshan charts for nouns and verbs.

For a given sentence after the word groups have been formed, each of the noun groups is tested against each row (called *karaka restriction*) in each karaka charts for each of the verb groups. When testing a noun group against a karaka restriction of a verb group, vibhakti information is checked, and if found satisfactory, the noun group becomes a candidate for the karaka of the verb group.

The above can be shown in the form of a constraint graph. Nodes of the graph are the word groups and there is an arc labeled by a karaka from a verb group to a noun group, if the noun group satisfies the karaka restriction in the karaka chart of the verb group. (There is an arc from one verb group to another, if the karaka chart of the former shows that it takes a sentential or verbal karaka.) The verb groups are called demand groups as they make demands about their karakas, and the noun groups are called source groups because they satisfy demands.

As an example, consider a sentence containing the verb KA (eat):

```
baccA  hATa se   kelA      KAtA hE.
-----  -------   ----      --------
child  hand -se  banana    eats
(The child eats the banana with his hand.)
```

Its word groups are marked by underlining, and KA (eat) has the same karaka chart as in Fig. 1. Its constraint graph is shown in Fig. 4.

A parse is a sub-graph of the constraint graph satisfying the following conditions:

(a) For each of the mandatory karakas in a karaka chart for each demand group, there should be exactly one out-going edge from the demand group labeled by the karaka.

(b) For each of the optional karakas in a karaka chart for each demand group, there should be at most one outgoing edge from the demand group labeled by the karaka.

(c) There should be exactly one incoming arc into each source group.

Efficient methods based on bipartite graph matching are known for finding solution graphs.

If several sub-graphs of a constraint graph satisfy the above conditions, it means that there are multiple parses and the sentence is ambiguous. If no sub-graph satisfies the above constraints, the sentence does not have a parse, and is probably ill-formed.

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